

Enhancing TCP Communication in Cognitive Radio Network

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Abstract

Cognitive Radio Network (CRN) is a high potential technology for future networks since the spectrum resources are limited and it will use channels effectively, it refers that systems are aware of context and are capable of reconfiguring themselves based on the surrounding environments and their own properties with respect to spectrum, traffic load, congestion situation, network topology, and wireless channel propagation. The role of TCP is crucial in cognitive radio. The Primary User occupying or releasing a communication channel in CRN is to be handled properly when secondary user is using it. To handle this issue there should be a cognitive communication between TCP & MAC. This paper investigates this issue to overcome the TCP throughput decay in cognitive radio networks to enhance the efficiency of communication.

Index Terms- Cognitive Radio, TCP, MAC, Spectrum sensing, wireless communication

1 INTRODUCTION

In Cognitive Radio Networks the Primary User (PU) with Licensed Band and the Secondary User (SU) with Unlicensed Band plays key role in using bandwidth efficiently. As per the statistics of Federal Communication Commission (FCC) in [2], the utilization of the allocated spectrum in a geographical region vary from 15% to 85%. Cognitive Radio networks enhance utilization of bandwidth by allowing the SU to use idle bands. The SU can use the licensed band when primary user is not using it, SU employ access mechanisms to transmit data when the spectrum opportunity appears and these mechanisms are known as opportunistic spectrum access (OSA)[3],[4],[5] but PU is the highest priority user; it can influence SU traffic by both accessing and leaving its bandwidth. The PU in CRN differentiates it from the other entire wireless network. If possible, SU should avoid the primary user & stop transmitting data when PU wants to use the same bandwidth. In Cognitive Radio Networks the main functions are spectrum sensing, spectrum management, spectrum mobility, spectrum sharing [3]. The SU will make a channel sensing schedule to use the best available channel & manage it from interference of PU as per the access schedule allotted. The TCP throughput decay in wireless network is mainly due to environmental factors. The parameters of the MAC/PHY layer is communicated to the TCP layer to enhance the throughput. The transmission behavior of TCP plays the key role in throughput decay, rather than MAC, The MAC/PHY layer information is responsible

for the SU to avoid the PU's interference. Therefore, the proposed solution investigates a cognitive communication between TCP & MAC that uses CR device information in cognitive radio networks to enhance the efficiency of communication.

In this paper, we study the issue to overcome the TCP throughput decay in cognitive radio networks and the proposed solutions for handling channel occupying or releasing by primary user when secondary user is using it. A packet loss due to the PU's interference can be sensed by a CR device, because the PU's signal can be identified by its characteristics [3]. The SU can easily distinguish the PU's interference from other packet loss. The channel where primary user is not using very much indicates that Secondary User have high bandwidth capacity on an average whereas in opposite case Secondary User have low bandwidth capacity on an average. These cases impact TCP throughputs leading to some error estimate information. For instance, the RTT value is probably over estimated in the case of low bandwidth capacity with low PU activity.

This paper is organized as follows. In Section II we will discuss background and related work. Then, the proposed works are described in Section III. Performance evaluation of our proposal is done in Section IV and Section V concludes the paper and discusses the future work.

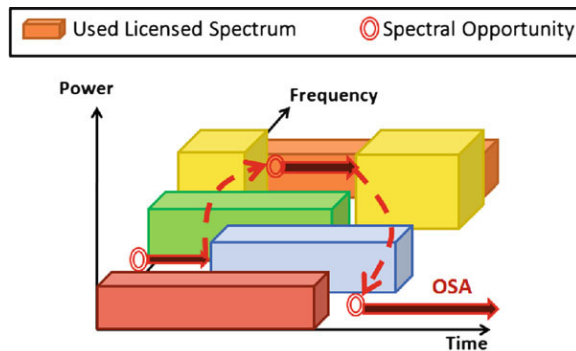


Fig1. Opportunistic Spectrum Access tracks

2 BACKGROUND & RELATED WORKS

2.1 Cognitive radio

Cognitive radio (CR) [6] is a high potential technology for communications and networking, it refers to the solution to the problem of spectrum scarcity. In CR communication the radio spectrum is used in an opportunistic manner, while PU is not using it. CR enabled devices continuously monitor their radio environment in order to find so-called spectrum holes, that is, channels which are unused at a particular time and location. Such bands are used for communication between CR devices. Since CR users are secondary users, they have also to constantly monitor the used band to detect any activity by primary users as soon as primary users appear, CR users have to take measures to avoid interfering with them, like e.g. moving to a different, free frequency band or reducing their transmission power. It is therefore of the utmost importance to understand the performance of CR systems, and especially the impact they may have on the performance of users applications and users experience.

Cognitive radio can be regarded as a software-defined radio (SDR), where a cognition cycle allows for wireless terminals to be known of their radio environment and to adapt to it accordingly [7].

2.2 TCP over Cognitive Radio networks

TCP is inefficient in CR networks for the following reasons [8]:

2.2.1 Channels with variable characteristics:

CR-enabled devices constantly monitor their radio environment to find spectrum holes that can be used. However each channel can have different characteristics in terms of bandwidth, loss and delay. TCP can be slow

to adapt to frequent changes in the bandwidth and is sensitive to loss and delay leading to efficiency deterioration.

2.2.2 Temporary disconnections due to spectrum sensing:

Devices with CR capabilities alternate between sensing mode and transmission mode. During sensing mode, the devices do not transmit the data and this can lead to sudden increase in round trip time (rtt). If TCP's RTO timer $TRTO < rtt + T_o$ then timeouts will occur during spectrum sensing period and TCP will set its congestion window (cwnd) to 1 and slow start threshold (sssthresh) is reduced to half of the previous value and TCP enters into the slow-start phase. This leads to the under-utilization of the available bandwidth as shown in [9].

2.2.3 Spectrum handover when primary users appear:

Whenever a primary user appears in a channel then secondary users have to vacate the channel and have to find another channel to use. In order to transit from one channel to another, the delay and the disconnection period involved can degrade TCP performance and also cause TCP round trip timer to expire reducing its efficiency.

2.3 CR MAC

Medium Access Control (MAC) protocols play an important role in cognitive radio (CR) networks. The state-of-the-art CR MAC [10] protocols according to the spectrum-sharing modes into two major types, i.e., overlay MAC and underlay MAC. In overlay MAC, secondary users (SUs) opportunistically access the licensed spectrum not occupied by primary users (PUs) and should vacate the spectrum when PUs return. On the contrary, in underlay MAC, SUs can continue using the spectrum when PUs return, but the interferences from SUs to PUs should be carefully controlled under the predefined interference thresholds.

The CR MAC acts as a bridge between the CR physical layer and the CR network layer. On the one hand, it can utilize the spectrum-sensing results from the CR physical layer, characterize the channels, and decide which channel to use and when to access. On the other hand, it can help the CR network layer to decide the routing path by reporting the characteristic information and the list of available channels. Also, the CR network layer can tell the CR MAC to choose a suitable channel for a dedicated quality-of-service (QoS) requirement. In general, the CR MAC should support the following two functions.

2.3.1 Interference control and avoidance for PUs:

This is the premise that SUs can share the spectrum with PUs. There are two modes for spectrum sharing between SUs and PUs. One is called overlay, wherein SUs should vacate the channel as soon as the PUs return. The other one is called underlay, wherein SUs can work in the same channel with PUs as long as the interference from SUs to PUs is no more than the predefined threshold.

2.3.2 Collision avoidance amongst SUs:

Because different SUs may coexist, collisions may happen if they simultaneously move to and use the same spectrum band according to their spectrum-sensing results. Thus, the CR MAC should control the spectrum access of different SUs to avoid the collisions.

2.4 Related Work

Since its introduction by Mitola [7], the concept of cognitive radio has been the subject of much research effort. Many solutions have been proposed in the related field to address TCP issues on cognitive radio network. A cognitive TCP for example, [12] suggests a TCP solution by adapting MAC/PHY parameters to improve throughput. The codec & modulation in the physical layer, and frame size in the MAC layer are able to change dynamically to maximize TCP throughput. TCP CRAHN [13] is a window-based, TCP-like spectrum-aware transport layer protocol for CR ad-hoc networks. The main idea of TCP CRAHN is to distinguishes between different spectrum specific conditions like (a) spectrum sensing and switching, (b) a PU sudden appearance, (c) SU's movement, and then to take state-dependent recovery actions. In the other words, [12], [13] focus on the cases of lower layers' influence on TCP. The TCP throughput decay is due to variance bandwidth in a CR environment. A throughput decay problem, which is due to improper congestion window decay while TCP flow passes the CR link, is studied. We consider the congestion window decay as a slight-level congestive loss to TCP.

3 PROPOSED WORK

As shown in Fig2. When primary user wants to access a channel when secondary user is using it, there will be a case of collision, and the secondary user should leave the occupied channel and give its access to primary user. Due to this interference secondary user may loss packets. When primary user leaves this occupied channel, Secondary user congestion event will occur

which will increase its bandwidth capacity. Due to these activities RTT in TCP will vary and bandwidth capacity of secondary user will change. To overcome this problem we use CR-MAC protocol [10]. This MAC protocol is based on the following characteristics: 1) Secondary User has a fixed MAC super-frame size & it will scan all channels and decides which channel to access in the beginning of each super frame. 2) N orthogonal channels for the Primary User and Secondary user to use without any interference with each other.

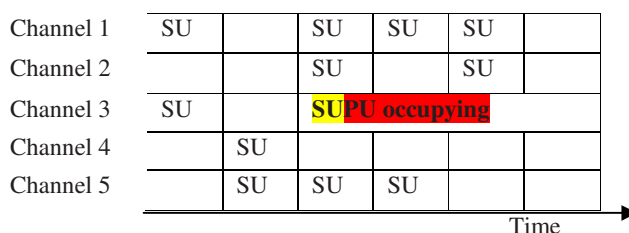


Fig2. PU Occupying Channel in MAC Super Frame

Secondary user can access all the channels simultaneously. The total bandwidth capacity is the aggregate of the entire channel it will use. 3) Secondary user will vacate all the channels in use whenever the Primary user accesses it. 4) Channel must contain at least one Primary User transmitter-receiver pair. 5) The MAC layer will provide historical channel utilization information of the Primary User and actual channel availability. 6) The MAC layer can differentiate between noise or another Secondary user signal & Primary user signal.

The CR-MAC characteristics (5) figure out the historical channel utilization of a PU and current channel availability. The PU's historical channel utilization indicates long-term trends of probability that a PU will interfere with a SU. This information also helps a SU to identify better channels (which mean less chance to be interrupted) to access. Next is current channel availability, a SU's maximum bandwidth capacity on a CR link can be derived from channel availability. Bandwidth capacity is a less time information for a MAC-super-frame. This information does not indicate actual value of the remaining availability of a CR link. Using the information from these cases we will investigate when TCP throughput decay occur. The long-term history of the link will provide general cases of the link. For instance when channel with less PU influence indicates that SUs have high bandwidth capacity on average. However, to a CR

link, bandwidth capacity may be temporarily low for unstable real-time channel availability. That is to say, short-term information probably shows opposing trends to long-term information in some rare cases. These rare cases impact TCP throughputs leading to some error estimate information. For instance, the RTT value is probably overestimated in the case of low bandwidth capacity with low PU activity.

Following information is required for cognitive communication between TCP & MAC:

- I. History of channel accessed by Primary user, describing that statistics when a Primary User will take access when Secondary user is using that channel.
- II. Available Channels, which helps secondary user to get the bandwidth capacity to reduce packet loss.
- III. To find out when TCP throughput decay occurs from the information provided by Cognitive Radio Devices.

When Secondary user access a channel in each MAC super frame, the packets lost due to Primary user interference loss event can be retransmitted in the beginning of the next super-frame rather than waiting for other retransmission mechanisms. If a PU interfere SU, the PU-interference handler [1] sends all packets in the congestion window again at the beginning of the next MAC super-frame. A worst-case may occur if the TCP's packets are retransmitted by the back-off mechanism: if a PU interfere SU exactly when that TCP backs-off, TCP clients may starve even if a PU's traffic load is light. The starvation, which causes throughput decline, is more serious when the MAC super-frame is longer. On the other hand, if the MAC super-frame is short, the collided packets are possibly recovered by MAC retransmission. By forcing the collided packets to be retransmitted at the beginning of the MAC super-frame, the starvation cases can be relaxed. However, forcing the packets to retransmit causes duplicate packets. To avoid decreasing the congestion window, ACKs of retransmitted packets are not counted into duplicate ACKs.

A faster-recovery mechanism [1] is implemented when a mild-congestion situation occurs; the TCP stores parameters of the congestion window (size, ssthresholds . . . etc.). After a period p , the TCP client tries to restore these parameters. Fig. 3 illustrates the idea of the faster recovery mechanism. Two problems of implementing the faster-recovery mechanism include: when to execute

(to differentiate a condition of low bandwidth capacity with low PU influence) and when to restore parameters (to find out p). Concerning the first case, we must differentiate the cases of "high bandwidth availability from low bandwidth availability in a low PU influence. A bandwidth availability estimator of a CR link is introduced by aggregating multiple ON-OFF traffic models.

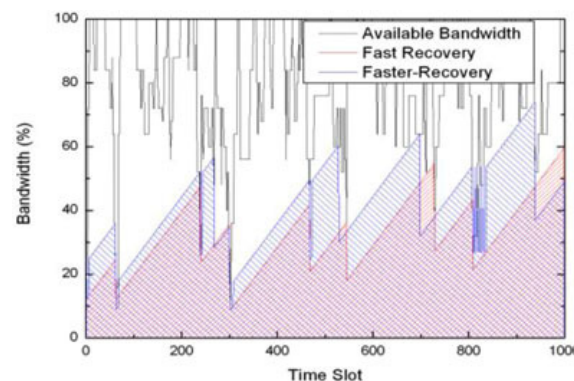


Fig3. Faster-recovery mechanism [1].

To distinguish between the high and low bandwidth availability of a particular PU activity case, a threshold that implies situations of rising/falling bandwidth availability is used. That is provided a certain PU activity ratio, the bandwidth capacity value of a congestion event is "high" or "low," and it can be driven from this threshold.

Table 1
Parameters of Simulation

Parameter	Value
Bandwidth per channel	100 Kbps, 1Mbps
Total Channel	10
PU Influence	1%,75%
Sensing Interval	1,2 seconds

4 RESULTS

Fig shows performance level to overcome the TCP throughput decay in cognitive radio networks for handling channel occupying or releasing by primary user when secondary user is using it. The study is done using NS-2. 10 channels are used in the CR link. An SU can use N channels simultaneously from 1 to 10. Channel has a fixed bandwidth during simulation. An SU senses a channel in every 2 second, IEEE 802.22 standard [14], and this interval equals the length of the MAC super-frame. Simulation parameters are arranged in Table2. Improvement in TCP throughput slightly decreases with increased channel bandwidth. The reason for that is the MAC can resend the collided packets

faster if the channel bandwidth is higher, which indicates that the TCP suffers a less packet timeout event. As a result, the TCP has less packet loss events due to PUs' influence.

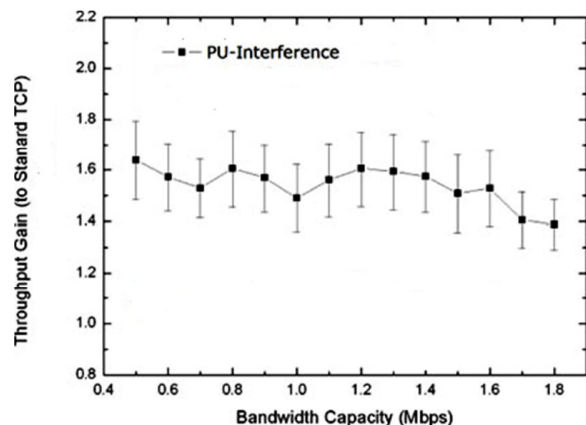


Fig4. Performance of PU in different Bandwidth Capacity.

5 CONCLUSION

In this paper, we investigate the TCP throughput decay problem arise in CRN due to PU & SU. We proposed a cognitive communication between TCP & MAC to enhance the performance of TCP over cognitive radio networks. Simulation results in Fig5.show that the proposed solution significantly improves TCP throughput over CRN in different situations. The performance of the proposed mechanism was evaluated and it showed significant improvement in terms of link utilization efficiency as compared to standard TCP. In future we would like to develop our simulator with more details related to micro mobility and new cognitive radio parameters.

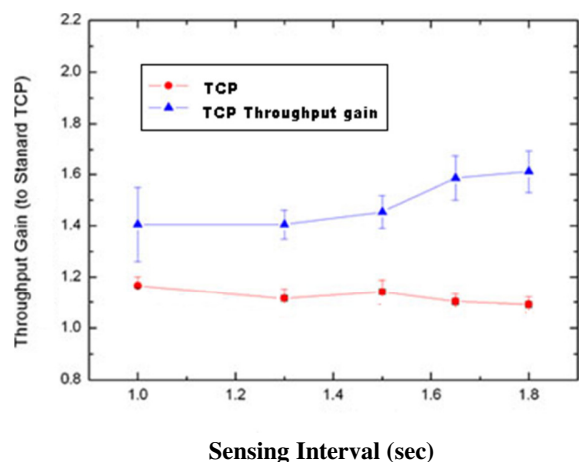


Fig5. Performance of TCP in sensing interval after throughput gain in Cognitive Radio Networks.

6 ACKNOWLEDGMENTS

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